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Claims

[c1] A micro electro-mechanical system (MEMS) variable capacitor comprising:
a fixed electrode formed on a substrate; and
two movable beams facing each other, each of said movable beams being respectively anchored to said substrate at at least one end thereof, said movable beams being formed by co-planar metal lines interconnected by a plurality of conductive vias, said conductive vias and said metal lines being embedded in insulating material, said movable beams further comprising a bottom electrode facing said fixed electrode, formed on the bottom surface of said insulating material, wherein the capacitance varies as a function of the sidewall overlap area of said two movable beams rotating with respect to one another.

[c2] The MEMS variable capacitor as recited in claim 1, wherein said fixed electrode is an actuating electrode for pulling down said movable beam.

[c3] The MEMS variable capacitoras recited in claim 1, wherein the material is selected from the group consisting of SiO_2, SiN, Si_3N_4, SiCOH, and SiCN.

[c4] The MEMS variable capacitoras recited in claim 1, wherein said electrodes are made of copper surrounded by a liner, said liner being made of a material selected from the group consisting of Ta, TaN, Ti, TiN, and W.

[c5] The MEMS variable capacitor as recited in claim 1, wherein said movable beams form a multi-layered metal structure.

[c6] The MEMS variable capacitor as recited in claim 1, wherein said via interconnections in one of said movable beams faces said via interconnections in said second movable beam for increased sidewall area and mechanical stability.

[c7] The MEMS variable capacitor as recited in claim 1, wherein the actuation electrodes are anchored to said substrate.

[c8] The MEMS variable capacitor recited in claim 1 wherein said bottom electrode is electrically insulated from said co-planar metal lines, and wherein a voltage that is applied between said fixed electrode and said bottom electrode creates an attraction force on said movable beam inducing movement.

[c9] The MEMS variable capacitor recited in claim 1, wherein said two movable beams form the two plates of the ca-

pacitors.

[c10] The MEMS variable capacitor recited in claim 1, wherein the space separating said fixed electrode from said bottom electrode is air, when said electrodes are not actuated .

[c11] The MEMS variable capacitor recited in claim 1, wherein said fixed electrode and said bottom electrodes are provided with an insulating layer to electrically insulating them from each other when said electrodes are actuated..

[c12] The MEMS variable capacitor recited in claim 1, wherein said movable electrodes are densely populated by way of said via interconnections to increase the sidewall area of said capacitor .

[c13] The MEMS variable capacitor recited in claim 1, wherein the number of said co-planar metal lines is maximized to increase the total capacitance of said variable capacitor.

[c14] A micro electro-mechanical system (MEMS) variable capacitor comprising:
a plurality of fixed electrodes formed on a substrate parallel to each other; and
movable beams facing each other and facing one of said

fixed electrodes, each of said movable beams being respectively anchored to said substrate at at least one end thereof, said movable beams being formed by co-planar metal lines interconnected by a plurality of conductive vias, said conductive vias and said metal lines being embedded in insulating material, said movable beams further comprising a movable electrode facing said fixed electrode, formed on the bottom surface of said insulating material, wherein the capacitance varies as a function of the total sidewall overlap area of said movable beams.

[c15] The MEMS variable capacitor recited in claim 14, wherein alternating movable electrodes of one polarity are attached to a metal strap and the remaining movable electrodes of opposing polarity are attached to a second metal strap.

[c16] The MEMS variable capacitor recited in claim 14 further comprising a plurality of movable electrodes, wherein at least one of said movable electrodes provides a signal path between said at least one movable electrode and its corresponding movable beam, forming a multiple-port MEMS variable capacitor.

[c17] The MEMS variable capacitor recited in claim 14, wherein said movable electrodes are attached to said substrate in a plurality of configurations.

[c18] The MEMS variable capacitor recited in claim 14, wherein said movable electrodes attached to said substrate are connected to an actuation pad for simultaneous actuation of said movable electrodes having the same polarity.

[c19] The MEMS variable capacitor recited in claim 14, wherein said movable electrodes attached to said substrate are connected to separate actuation pads for an independent actuation of said movable electrodes of opposite polarity.

[c20] The MEMS variable capacitor recited in claim 14, wherein movable electrodes are curled up or down due to relaxation of residual stresses in said metal lines and said associated insulating material.

[c21] The MEMS variable capacitor recited in claim 14, wherein said movable electrodes are attached on one end leading to an electrode to form a cantilever beam.

[c22] The MEMS variable capacitor recited in claim 14, wherein said movable electrodes are attached on both ends to form a fixed beam.

[c23] The MEMS variable capacitor recited in claim 14, wherein the support structures reduce the mechanical stiffness of said movable electrodes.

[c24] The MEMS variable capacitor recited in claim 14, wherein a second substrate encapsulates said variable capacitor in dielectric.

[c25] The MEMS variable capacitor recited in claim 24, wherein said second substrate is made of inorganic material or semiconductor material.